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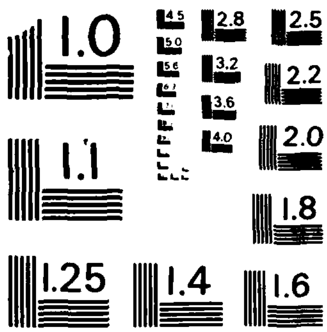

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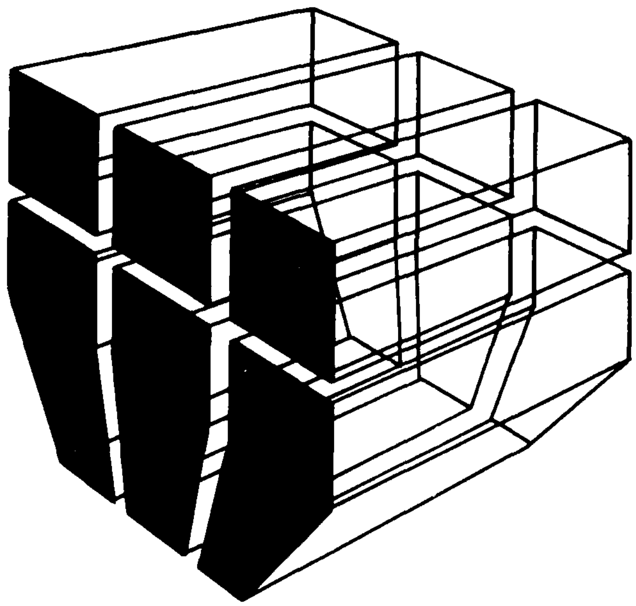
June 1986
DEH Equipment Maintenance Management

AD-A169 716

A Model for Analysis of Alternative Performance Structures for Vehicle Maintenance Functions of U.S. Army Installation Directorates of Engineering and Housing

by
Patrick J. Tanner
Kaan R. Aytogu



Factors influencing vehicle maintenance responsiveness at Army installations were investigated and effects of different performance structures on vehicle downtime were determined. The primary factor influencing vehicle maintenance was found to be turnaround time, which in turn is influenced by factors such as workload, available workforce, maintenance priorities, the parts ordering process, and organizational structure. Responsiveness and productivity parameters related to these factors were developed and used to build a model for determining the optimal performance structure at a given installation. An example application of the model to Fort Benning showed that consolidating vehicle maintenance under the Directorate of Engineering and Housing would result in an annual savings of $44,807, while consolidation under the Directorate of Industrial Operations would result in an annual disbenefit of $933,977.

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FOREWORD

This investigation was performed for the Office of the Assistant Chief of Engineers (OACE) under Project 4A162731AT41, "DEH Equipment Maintenance Management"; Task C, "Investigate the Desirability of the DEH Maintenance Organizations to Perform Intermediate Level Maintenance;" Work Unit 056, "DEH Equipment Maintenance Management." The OACE Technical Monitor is Mr. Walter Seip, DAEN-ZCF-B.

The work was done by the Facilities Engineering Management Team, Facility Systems Division (CERL-FS), U.S. Army Construction Engineering Research Laboratory (USA-CERL).

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A MODEL FOR ANALYSIS OF ALTERNATIVE PERFORMANCE STRUCTURES FOR VEHICLE MAINTENANCE FUNCTIONS OF U.S. ARMY INSTALLATION DIRECTORATES OF ENGINEERING AND HOUSING

1 INTRODUCTION

Background

At most Army installations, two organizations are involved in engineer vehicle maintenance: the Directorate of Industrial Operations (DIO) and the Directorate of Engineering and Housing (DEH). The way in which these two organizations interact to perform different levels of maintenance varies among different installations. In some cases, the DEH performs organizational level* (less complex) maintenance, while the DIO is responsible for intermediate level (more complex) maintenance; in others, the DEH performs both organizational and intermediate levels of maintenance; and in still others, the DIO performs both levels of maintenance. Determining the impact of this performance structure, as well as other factors that influence maintenance responsiveness within the DEH organizations, is a necessary step in achieving better maintenance productivity and decreased vehicle downtime.

Objective

The objectives of this study were (1) to investigate the factors influencing vehicle maintenance responsiveness, (2) to determine the effects of different performance structures on vehicle downtime within the DEH organization, (3) to develop a model for determining the optimal performance structure for improving maintenance productivity at a given installation, and (4) to apply the model to a representative installation.

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*Organizational and intermediate levels of maintenance are defined in detail in the Glossary, pp 64.

Approach

Maintenance data were collected from 1983-84 records at three installations, and DEH personnel were surveyed and interviewed at 18 installations. The data were summarized and grouped into three basic performance structure alternatives for further analysis. The parameters found to influence maintenance responsiveness were used to develop a model for decision-makers to use in determining the most effective performance structure for a given installation. This model was used to analyze the vehicle maintenance functions at Fort Benning, GA, which is representative of installations where the DEH performs organizational maintenance only.

Scope

This study is an analysis of factors influencing vehicle maintenance procedures used in the DEH maintenance shops; it is not an investigation of repair methods. Also, DEH organizations where all maintenance is performed by a contractor are outside the scope of this work.

2 DEVELOPMENT OF THE MODEL

Data Collection

Information was gathered from maintenance shops performing different levels of maintenance. Actual 100 percent performance data were collected from 1983-84 records at Fort Benning, GA (organizational maintenance only); Fort Lewis, WA (organizational and intermediate maintenance); and Fort Dix, NJ (organizational and intermediate maintenance). These installations provided a good representation of size and performance structure.

The following data were collected from information recorded on DA Forms 2404, 2405, and 2407:

1. Equipment Category Code
2. Vehicle Identification Number
3. Maintenance Action Number
4. Actual Age
5. Actual Mileage
6. Actual Operating Hours
7. Description of the Vehicle
8. Warranty Claim
9. Description of the Maintenance Action
10. Turnaround Time
11. Level of Maintenance Performance (Organizational, Intermediate, Scheduled)
12. Job Order Number
13. Date Job Order Received
14. Date Repair Started
15. Date Repair Finished
16. Man-Hours Involved for Maintenance
17. Cost of Direct Labor
18. Cost of Parts
19. Total Cost of Maintenance
20. Organizational Performance (DEH, DIO).

These 20 data elements were recorded for 7498 maintenance actions at Fort Benning, 4924 maintenance actions at Fort Lewis, and 3894 maintenance actions at Fort Dix. The maintenance data, totaling 4.9 megabytes of information,

were entered into a microcomputer database structure called R-BASE 4000 for further analysis. Tables 1, 2, and 3 summarize the data collected for Forts Benning, Dix, and Lewis, respectively.

In addition to this quantitative effort, data were collected at 18 installations* through surveys and interviews with DEH and DIO maintenance management personnel including the chief of the Buildings and Grounds Section, the foreman of the maintenance shop, and the supervisor of the maintenance shop. The following information was sought:

1. Definition of when it is desirable for DEH organizations to perform intermediate level maintenance.

2. Determination of important factors which influence the decision on whether to perform intermediate level maintenance in the DEH maintenance shops.

3. Determination of primary factors influencing vehicle downtime for intermediate and organizational maintenance cases.

4. Determination of DIO priority for DEH maintenance actions.

5. Determination of effective shop rate at DEH and DIO organizations.

6. Definition of cost factors associated with upgrading maintenance facilities to perform higher level maintenance.

7. Definition of the parts ordering process.

8. Determination of cost factors associated with inspections done at DIO and DEH organizations.

9. Determination of costs associated with transporting vehicles from DEH to DIO (for DEH shops whose intermediate cases were handled at DIO facilities).

Interview data indicated that turnaround time for a maintenance action--whether it is organizational or intermediate--was thought to be one of the

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*Fort Benning, GA; Fort Lewis, WA; Fort Dix, NJ; Fort Drum, NY; Fort Indiantown Gap, PA; Presidio of San Francisco, CA; Fort Wainwright, AK; Fort Irwin, CA; Fort A. P. Hill, VA; Fort Pickett, VA; Fort Hood, TX; Fort McCoy, WI; Fort Richardson, AK; Fort Bragg, NC; Fort Polk, LA; Fort Greely, AK; Fort Riley, KS; and Fort Carson, CO.

Table 1

Maintenance Performance of the DEH Shop at Fort Benning

Total Number of Maintenance Actions Pecorded during FY83 and FY84	7498
Total Number of Vehicle Equivalents for the Vehicles/Equipment that DEH Shop is Responsible for Maintaining Regardless of the Owning Command or Using Organization	1181.2
Vehicle Equivalents per Employee	44.9
Total Number of Organizational Maintenance Cases	7324
Total Number of Intermediate Maintenance Cases	171
Average Turnaround Time (in Days)	6.0
Average Turnaround Time for Organizational Maintenance Cases (in Days)	5.2
Average Turnaround Time for Intermediate Maintenance Cases (in Days)	45.3
Average Man-Hours Involved for Maintenance	3.8
Average Man-Hours Involved for Organizational Maintenance Cases	3.7
Average Man-Hours Involved for Intermediate Maintenance Cases	33.5
Average Labor Cost per Maintenance Action	44.06
Average Labor Cost per Organizational Maintenance Case	43.7
Average Labor Cost per Intermediate Maintenance Case	482.16
Average Cost of Parts per Maintenance Action	133.80
Average Costs of Parts per Organizational Maintenance Case	107.38
Average Cost of Parts per Intermediate Maintenance Case	1101.38

Table 2

Maintenance Performance of the DEH Shop at Fort Dix

Total Number of Maintenance Actions Recorded during FY83 and FY84	3384
Total Number of Vehicle Equivalents for the Vehicles/Equipment that DEH Shop is Responsible for Maintaining Regardless of the Owning Command or Using Organization	915.5
Vehicle Equivalents per Employee	70.4
Total Number of Organizational Maintenance Cases	3211
Total Number of Intermediate Maintenance Cases	102
Average Turnaround Time (in Days)	4.3
Average Turnaround Time for Organizational Maintenance Cases (in Days)	4.1
Average Turnaround Time for Intermediate Maintenance Cases (in Days)	23.9
Average Man-Hours Involved for Maintenance	3.03
Average Man-Hours Involved for Organizational Maintenance Cases	2.8
Average Man-Hours Involved for Intermediate Maintenance Cases	17.5
Average Labor Cost per Maintenance Action	43.04
Average Labor Cost per Organizational Maintenance Case	39.30
Average Labor Cost per Intermediate Maintenance Case	298.05
Average Cost of Parts per Maintenance Action	131.22
Average Costs of Parts per Organizational Maintenance Case	108.78
Average Cost of Parts per Intermediate Maintenance Case	1105.18

Table 3

Maintenance Performance of the DEH Shop at Fort Lewis

Total Number of Maintenance Actions Recorded during FY83 and FY84	4924
Total Number of Vehicle Equivalents for the Vehicles/Equipment that DEH Shop is Responsible for Maintaining Regardless of the Owning Command or Using Organization	1331.1
Vehicle Equivalents per Employee	70.0
Total Number of Organizational Maintenance Cases	4410
Total Number of Intermediate Maintenance Cases	481
Average Turnaround Time (in Days)	10.7
Average Turnaround Time for Organizational Maintenance Cases (in Days)	9.7
Average Turnaround Time for Intermediate Maintenance Cases (in Days)	19.1
Average Man-Hours Involved for Maintenance	9.5
Average Man-Hours Involved for Organizational Maintenance Cases	8.9
Average Man-Hours Involved for Intermediate Maintenance Cases	13.6
Average Labor Cost per Maintenance Action	113.78
Average Labor Cost per Organizational Maintenance Case	106.48
Average Labor Cost per Intermediate Maintenance Case	173.14
Average Cost of Parts per Maintenance Action	100.14
Average Costs of Parts per Organizational Maintenance Case	84.47
Average Cost of Parts per Intermediate Maintenance Case	299.75

most influential factors on the overall productivity of the DEH maintenance activity. For this study, the turnaround time for a maintenance action is defined as follows:

(Turnaround Time) = (Date Repair Finished) - (Date Job Order Received)

Alternative Performance Structures

A common baseline structure of the DEH organization was developed based on the surveys and interviews. In addition to the baseline structure, two alternative performance structures were considered.

Baseline Structure

It is common in most TRADOC installations that DEH maintenance shops perform only organizational level maintenance, while intermediate level maintenance actions are sent to DIO maintenance shops. Because of the tactical nature of the DIO mission, the DEH intermediate cases sent to DIO usually receive maintenance priority 11, 12, or 13--the lowest maintenance priorities in DIO facilities--depending on the DIO workload. This low priority has a significant effect on vehicle downtime.

The most common vehicle maintenance flowchart for this baseline structure is given in Appendix A. Fort Benning is representative of this structure.

Alternative Structure 1

In this alternative structure the DEH maintenance shops perform both organizational and intermediate level maintenance at DEH facilities. Forts Dix and Lewis are representative of this structure.

Alternative Structure 2

In this alternative structure, the DIO maintenance shops perform both organizational and intermediate maintenance for DEH at DIO facilities.

Table 4 summarizes the three alternative structures.

Table 4

Summary of Alternative Performance Structures

Alternative Performance Structures	Organization Performing DEH-Organizational Maintenance Cases	Organization Performing DEH-Intermediate Maintenance Cases
Baseline	DEH	DIO
Alternative 1	DEH	DEH
Alternative 2	DIO	DIO

Definition of the Parameters

This section identifies the parameters affecting maintenance responsiveness and describes how they were used in developing the decision-making model. Table 5 summarizes the 12 parameters and Appendix B is a detailed discussion on obtaining mathematical formulas for these parameters.

It is useful to define maintenance performance costs based on the levels of maintenance such as organizational and intermediate because the decision-making model is related to the performance structure.

The first parameter of concern is the annual cost of intermediate maintenance cases. This parameter, P_1, can be estimated from the average man-hours involved in intermediate maintenance cases, number of intermediate cases per year, and the effective shop rate* of the organization performing the intermediate maintenance. This parameter may differ for each installation based on the specific labor rates, operating and administrative overhead costs, and the average man-hours involved on maintenance cases.

Similarly, another parameter, P_2, can be defined as the annual cost of organizational maintenance cases. P_2 is defined in terms of the average man-hours involved for organizational maintenance cases, number of organizational

*Effective shop rate can be determined by adding the average hourly labor rate of the maintenance shop, the administrative overhead cost, and the operational overhead cost.

Table 5

Summary of Parameters

Parameter	Definition
P_1	Annual cost of intermediate level maintenance cases.
P_2	Annual cost of organizational level maintenance cases.
$P_{3_{b-a}}$	Annual cost difference related to the change in DEH inventory for intermediate maintenance cases due to choosing alternative b over alternative a.
$P_{4_{b-a}}$	Annual cost difference related to the change in DEH inventory for organizational maintenance cases due to choosing alternative b over alternative a.
$P_{5_{b-a}}$	Annual intermediate maintenance cost difference related to the change in utilization due to choosing alternative b over alternative a.
$P_{6_{b-a}}$	Annual organizational maintenance cost difference related to the change in utilization due to choosing alternative b over alternative a.
P_7	Annual inspection cost of intermediate maintenance cases.
P_8	Annual inspection cost of organizationl maintenance cases.
P_9	Annual transportation cost of a vehicle for intermediate maintenance costs.
P_{10}	Annual cost associated with the parts ordering process for intermediate maintenance costs.
P_{11}	Annual cost associated with the parts ordering process for organizational maintenance cases.
P_{12}	Total estimated cost of upgrading the maintenance facility when choosing the optimal alternative.

maintenance cases per year, and the effective shop rate for the organization performing the organizational maintenance.

Cost of parts is not included in parameters P_1 and P_2 because it has been assumed that the purchase price of a part will be similar whether the organization is baseline structure, alternative structure 1, or alternative structure 2. However, cost associated with the parts ordering process has been considered in the model as a separate parameter and is discussed later in this section.

The next two cost parameters are directly related to vehicle downtime and its effects on the DEH inventory. It is assumed that as the turnaround time increases (or the vehicle downtime increases), more vehicles must be leased or purchased to perform the tasks which are not completed because a specific vehicle is not available. As a result, an increase in vehicle downtime will result in increased DEH vehicle inventory. Conversely, reduced downtime will decrease the DEH vehicle inventory requirement. These increases and decreases are reflected as disbenefit or benefit parameters in the decision-making model.

The parameter $P_{3_{b-a}}$ is defined as the cost difference related to the change in DEH inventory for intermediate maintenance cases due to choosing an alternative structure (alternative b) over the existing structure (alternative a). Inputs such as average turnaround time for intermediate maintenance cases, total DEH inventory, utilization of DEH vehicles, and total annual days down for intermediate maintenance are determined for alternatives a and b. Then, these inputs are used to compute the ratio of DEH fleet size under alternative b to the DEH fleet size under alternative a. The product of this ratio and the present value of the DEH inventory under the existing structure will result in $P_{3_{b-a}}$.

Similarly, $P_{4_{b-a}}$ is defined as the cost difference related to the change in DEH inventory for organizational maintenance cases due to choosing an alternative structure (alternative b) over the existing structure (alternative a). Average turnaround time for organizational maintenance cases, total DEH inventory, utilization of DEH vehicles, and total annual days down for organizational maintenance are used to compute the ratio of DEH fleet sizes under the alternative structure and existing structure. The product of this ratio

and the present value of the DEH inventory is used to determine the cost parameter $P_{4_{b-a}}$.

Besides affecting the DEH inventory size, turnaround time also affects the utilization of DEH vehicles: decreased turnaround time may result in greater use, which may in turn cause more organizational and intermediate maintenance. Therefore, another parameter has been defined to reflect the impacts of turnaround time on the decision-making model. $P_{5_{b-a}}$ is the intermediate maintenance cost difference related to the change in use resulting from choosing an alternative structure (alternative b) over the existing structure (alternative a). The average cost of intermediate maintenance cases, number of intermediate maintenance cases per year, total available vehicle days, and total days down for intermediate maintenance under alternatives a and b are used to compute this parameter.

A similar parameter has been defined for organizational maintenance cases. $P_{6_{b-a}}$ is the organizational maintenance cost difference related to the change in use caused by choosing an alternative structure (alternative b) over the existing structure (alternative a). This parameter is computed from inputs such as the number of organizational maintenance cases per year, the average cost of organizational maintenance, total available vehicle days, and total days down for organizational maintenance under alternatives a and b.

The next several parameters relate directly to the organizational aspects of maintenance performance at DEH and DIO shops. The first parameters are associated with the cost of maintenance inspections. Not only can the total inspection time spent on each maintenance action vary significantly from one organization to another, the time spent on the inspection of intermediate maintenance cases also varies from the inspection time of organizational maintenance cases.

Parameter P_7 is defined as the annual inspection cost of intermediate maintenance cases. This parameter is a function of the average time spent for the inspection of intermediate maintenance cases, number of intermediate cases per year, and the effective shop rate for the maintenance shop performing the intermediate maintenance. In the case of baseline structure, inspection for intermediate maintenance cases is done both at DEH and DIO shops; therefore, parameter P_7 for this alternative will include the inspection time spent at DEH and DIO and their respective shop rates.

Similarly, parameter P_8 is defined as the annual inspection cost of organizational maintenance cases. Average time spent for the inspection of organizational maintenance cases, number of organizational maintenance cases per year, and the effective shop rate are used to determine this parameter.

Another parameter of concern is the cost of transporting a vehicle from DEH shop to DIO for intermediate maintenance. This parameter, P_9, will be zero for alternative structures 1 and 2. Average time spent for transporting a vehicle from DEH to DIO, number of intermediate maintenance cases per year, and the effective shop rate are used to determine P_9.

Two parameters relate to the parts ordering process in DIO and DEH shops. The parameter P_{10} is defined as the annual cost associated with the parts ordering process for intermediate maintenance cases. P_{10} is determined using effective shop rate of the organization performing intermediate maintenance, number of intermediate maintenance cases per year, and the average time spent for parts ordering. The parameter P_{11} is defined as the annual cost associated with the parts ordering process for organizational maintenance cases, and has similar inputs.

Finally, the parameter $P_{12_{b-a}}$ is defined as the total estimated cost of upgrading the maintenance facility when choosing the optimal alternative. P_{12} includes the estimated cost of new tools, equipment, additional mechanics, and the space needed to upgrade the maintenance facility.

Decision Making Model

The model is based on the concept of the incremental benefit/cost ratio. The savings resulting from the cost differences between the alternative structures are the benefits, and the expenditures associated with upgrading the maintenance facilities are the costs. The incremental benefit-cost ratio is defined as:

$$\Delta \frac{B}{C} = \frac{B_{b-a}}{C_{b-a}} \qquad \text{(Eq 1)}$$

where

B_{b-a} = Incremental benefits of an alternative structure (b) over the existing structure (a).

C_{b-a} = Incremental cost of an alternative structure (b) over the existing structure (a).

Eq 1 can be rewritten as

$$\Delta \frac{B}{C} = \frac{\sum_{i=1}^{n} B_{i_{b-a}}}{C_{b-a}} \qquad \text{(Eq 2)}$$

where

$B_{i_{b-a}}$ = Individual incremental benefit of alternative structure (b) over the existing structure (a)

n = 11.

Furthermore, benefits can be defined in terms of differences between the cost parameters as shown below:

$$\sum_{i=1}^{n} B_{i_{b-a}} = \sum_{i=1}^{n} (P_{i_a} - P_{i_b}) \qquad \text{(Eq 3)}$$

where $(P_{i_a} - P_{i_b})$ is the difference between the cost parameters associated with the existing structure (a) and alternative structure (b). When $(P_{i_a} - P_{i_b})$ is positive, it becomes a benefit figure for alternative structure (b) and disbenefit figure for the existing structure (a). Conversely, when $(P_{i_a} - P_{i_b})$ is negative, it becomes a benefit figure for the existing structure (a) and disbenefit figure for the alternative structure (b).

When Eq 3 is substituted into Eq 2:

$$\Delta \frac{B}{C} = \frac{\sum_{i=1}^{n} (P_{i_a} - P_{i_b})}{C_{b-a}} \qquad \text{(Eq 4)}$$

Furthermore, the term C_{b-a} [cost of alternative structure (b) over the existing structure (a)] will be rewritten as P_{12} (total estimated cost of upgrading the maintenance facility when choosing the optimal structure), and parameters P_1 through P_{11} will be used to determine the incremental benefits as follows:

$$\sum_{i=1}^{11} B_{i_{b-a}} = (P_{1_a} - P_{1_b}) + (P_{2_a} - P_{2_b}) + (P_{3_{b-a}})$$
$$+ (P_{4_{b-a}}) + (P_{5_{b-a}}) + (P_{6_{b-a}})$$
$$+ (P_{7_a} - P_{7_b}) + (P_{8_a} - P_{8_b})$$
$$+ (P_{9_a} - P_{9_b}) + (P_{10_a} - P_{10_b})$$
$$+ (P_{11_a} - P_{11_b}) \qquad \text{(Eq 5)}$$

Finally, the decision-making model can be rewritten as:

$$\Delta \frac{B}{C} = \frac{\sum_{i=1}^{11} B_{i_{b-a}}}{P_{12}} \qquad \text{(Eq 6)}$$

Acceptance and Rejection Criteria

When P_{12} is zero, there is no need to compute $\Delta \frac{B}{C}$. In this case, if $B_{i_{b-a}}$ is positive, it suggests that alternative b is better than alternative a and there is no cost associated with achieving the benefits; if $B_{i_{b-a}}$ is negative, it suggests that alternative b is not better than alternative a; and if $B_{i_{b-a}}$ is zero, then both alternatives are indifferent.

Equation 6 represents the ratio of the incremental benefits to incremental cost when choosing alternative b over alternative a. A ratio less than zero suggests that annual benefits of alternative b are less than annual benefits of alternative a, hence alternative b is not better than alternative a. A ratio of zero means that annual benefits of alternative b and a are the same. A ratio between 0 and 1 suggests that annual benefits of b are more

than annual benefits of a, but that the cost of obtaining annual benefits of b over a cannot be economically justified for the first year. If the ratio is 1, cost of obtaining annual benefits of b over a is justified by the first year benefits. Finally, if the ratio is greater than 1, alternative b is better than alternative a and cost of obtaining annual benefits is covered by the first year derived benefits.

The incremental benefit-cost ratio establishes the decision-making criteria for the baseline, alternative structure 1, and alternative structure 2, which are displayed in Tables 6, 7, and 8, respectively.

Once the alternative structure has been chosen using the incremental benefit/cost model, the decision-maker should investigate the economic feasibility of the alternative. The incremental benefit-cost model determines the optimal alternative to be the one with the maximum value of benefit-cost ratio among all possible alternatives. However, the benefit-cost ratio for the optimal alternative may not be 1.0 or greater than 1.0 (i.e., Benefits = Cost, or Benefits > Costs, respectively). If the benefit-cost ratio has a value less than 1.0, benefits of the optimal alternative--which is the best among all possible alternatives based on the incremental benefit-cost ratio--do not justify the cost(s) of the optimal alternative for the first year. The decision-making model considers the cost of the alternatives to be the fixed cost, i.e., cost of upgrading the facilities. Therefore, the cost of upgrading the maintenance facilities may not be economically justifiable based on the benefits of the first year.

In summary, if the benefit-cost ratio of the optimal alternative is greater than 1.0, it suggests that the fixed cost of upgrading the maintenance facilities will be recovered by the benefits of the optimal alternative at the end of the first year. On the other hand, if the benefit-cost ratio of the optimal alternative is less than 1.0, it suggests that the fixed cost of upgrading the maintenance facilities will not be recovered by the benefits of the alternative at the end of the first year. In the latter case, the decision-maker needs to calculate the breakeven point to justify the cost over

Table 6

Acceptance and Rejection Criteria for the Baseline Structure

Condition	Decision
$(\Delta\ B/C)_{\text{baseline - alternative 1}} \geq 1$ and $(\Delta\ B/C)_{\text{baseline - alternative 2}} \geq 1$	Accept the Baseline
$0 < (\Delta\ B/C)_{\text{baseline - alternative 1}} < 1$ and $0 < (\Delta\ B/C)_{\text{baseline - alternative 2}} < 1$	Accept the Baseline
$0 < (\Delta\ B/C)_{\text{baseline - alternative 1}} < 1$ and $(\Delta\ B/C)_{\text{baseline - alternative 2}} \geq 1$	Accept the Baseline
$0 < (\Delta\ B/C)_{\text{baseline - alternative 2}} < 1$ and $(\Delta\ B/C)_{\text{baseline - alternative 1}} \geq 1$	Accept the Baseline
Otherwise	Reject the Baseline

Table 7

Acceptance and Rejection Criteria for Alternative Structure 1

Condition	Decision
$(\Delta B/C)_{\text{alternative 1 - alternative 2}} \geq 1$ and $(\Delta B/C)_{\text{alternative 1 - baseline}} \geq 1$	Accept Alternative 1
$0 < (\Delta B/C)_{\text{alternative 1 - alternative 2}} < 1$ and $0 < (\Delta B/C)_{\text{alternative 1 - baseline}} < 1$	Accept Alternative 1
$0 < (\Delta B/C)_{\text{alternative 1 - alternative 2}} < 1$ and $(\Delta B/C)_{\text{alternative 1 - baseline}} \geq 1$	Accept Alternative 1
$0 < (\Delta B/C)_{\text{alternative 1 - baseline}} < 1$ and $(\Delta B/C)_{\text{alternative 1 - alternative 2}} \geq 1$	Accept Alternative 1
Otherwise	Reject Alternative 1

Table 8

Acceptance and Rejection Criteria
for Alternative Structure 2

Condition	Decision
$(\Delta B/C)_{\text{alternative 2 - alternative 1}} \geq 1$ and $(\Delta B/C)_{\text{alternative 2 - baseline}} \geq 1$	Accept Alternative 2
$0 < (\Delta B/C)_{\text{alternative 2 - alternative 1}} < 1$ and $0 < (\Delta B/C)_{\text{alternative 2 - baseline}} < 1$	Accept Alternative 2
$0 < (\Delta B/C)_{\text{alternative 2 - alternative 1}} < 1$ and $(\Delta B/C)_{\text{alternative 2 - baseline}} \geq 1$	Accept Alternative 2
$0 < (\Delta B/C)_{\text{alternative 2 - baseline}} < 1$ and $(\Delta B/C)_{\text{alternative 2 - alternative 1}} \geq 1$	Accept Alternative 2
Otherwise	Reject Alternative 2

the benefits. The breakeven point--number of years to cover the fixed cost of the alternative--could be simply found by the following formula:

$$\begin{pmatrix}\text{Present}\\ \text{Value}\\ \text{of the}\\ \text{Cost}\end{pmatrix} = \begin{pmatrix}\text{Annual}\\ \text{Benefits}\end{pmatrix}\left[\frac{\left(1 + (\text{Interest Rate})\right)^{n} - 1}{(\text{Interest Rate})\left(1 + (\text{Interest Rate})\right)^{n}}\right] \qquad \text{(Eq 7)}$$

where n is the breakeven point, i.e., the number of years to cover the fixed cost of the alternative.[1]

Factors Influencing Vehicle Maintenance Responsiveness

In developing the parameters, it became obvious that turnaround time is the most influential factor affecting the parameters (see the detailed development of parameters 3, 4, 5, and 6 in Appendix B and the values of these parameters in Tables 1, 2, and 3).

Turnaround time is in turn affected by factors such as the workload, available workforce, maintenance priorities, organizational structure, parts ordering process, and maintenance performance structures based on the level of maintenance activity. Thus, achieving increased responsiveness through reduced turnaround time for maintenance actions could reduce vehicle downtime significantly.

[1]Lynn E. Bussey, The Economic Analysis of Industrial Projects (Prentice- Hall Press, 1978).

3 APPLICATION OF THE MODEL AT FORT BENNING

In this chapter, the decision-making model introduced in Chapter 2 is applied to the DEH shop at Fort Benning to determine the optimal maintenance performance structure for achieving increased maintenance productivity at that installation.

It should be noted that the calculations made for determining the values for some of the parameters for Fort Benning--such as average time for inspections, average time for parts ordering process, transportation time--were based on information gathered from vehicle maintenance management personnel rather than using techniques such as time-study and motion-study.

Comparing Alternative Structure 1 with the Baseline Structure

To determine the incremental benefit-cost ratio for Fort Benning if the DEH were to perform both organizational and intermediate maintenance (alternative structure 1) instead of performing only organizational maintenance (baseline structure), parameters P_1 through P_{12} will be determined for the baseline structure using the Fort Benning data, and the same parameters for alternative structure 1 will be determined using Fort Dix and Fort Lewis data, with some adjustment factors as described in the appendices. Table 9 summarizes the results of the incremental benefit-cost ratio analysis and Appendix C contains the detailed calculations.

The results obtained in Table 9 suggest a total annual benefit of $44,807 for Fort Benning if alternative structure 1 is chosen over the existing structure (baseline). The estimated cost of implementing alternative structure 1 (P_{12}) was unavailable from the DEH officials at Fort Benning. However, if P_{12} were estimated to be $25,000, a reasonable cost for upgrading existing facilities, the incremental benefit-cost ratio for this comparison results in

$$(\Delta \frac{B}{C})_{\text{alternative 1 - baseline}} = \frac{44,807}{25,000} = 1.79$$

Table 9

Analysis of Alternative Structure 1 vs. Baseline Structure for Fort Benning-DEH

P_{1} alternative 1 - baseline	- $5,330
P_{2} alternative 1 - baseline	- $25,331
P_{3} alternative 1 - baseline	+ $84,931
P_{4} alternative 1 - baseline	0
P_{5} alternative 1 - baseline	- $318
P_{6} alternative 1 - baseline	0
P_{7} alternative 1 - baseline	+ $5,091
P_{8} alternative 1 - baseline	- $10,162
P_{9} alternative 1 - baseline	$2,985
P_{10} alternative 1 - baseline	- $553
P_{11} alternative 1 - baseline	- $6,506
	$44,807
P_{12}	Not available (Assume 25K)

This result suggests that it is beneficial to implement alternative structure 1 at Fort Benning DEH and it would take less than a year to cover the cost of obtaining the benefits.

Comparing Alternative Structure 2 with the Baseline Structure

The incremental benefit-cost ratio if the DIO were to perform both organizational and intermediate maintenance (alternative structure 2 instead of baseline) is summarized in Table 10 and detailed in Appendix D.

The results in Table 10 suggest a total annual disbenefit of -$933,977 for Fort Benning if alternative 2 is chosen over the baseline. It is thus infeasible to compute Δ B/C since this analysis shows it is not beneficial to implement alternative structure 2 at Fort Benning.

Comparing Alternative Structure 1 with Alternative Structure 2

Table 11 summarizes the results of this incremental benefit-cost ratio analysis and Appendix E details the calculations.

The results in Table 11 suggest a total annual benefit of $985,648 for Fort Benning if alternative 1 is chosen over alternative 2. If cost of implementing alternative structure is assumed to be $25,000 ($P_{12}$), it will take less than a year to recover the cost of obtaining the benefits.

Table 12 summarizes total benefits (disbenefits) of the three alternatives analyzed.

Table 10

Analysis of Alternative Structure 2 vs. Baseline Structure for Fort Benning-DEH

$P_{1\,\text{alternative 2 - baseline}}$	- $6,425
$P_{2\,\text{alternative 2 - baseline}}$	- $30,554
$P_{3\,\text{alternative 2 - baseline}}$	0
$P_{4\,\text{alternative 2 - baseline}}$	- $870,629
$P_{5\,\text{alternative 2 - baseline}}$	0
$P_{6\,\text{alternative 2 - baseline}}$	+ $13,973
$P_{7\,\text{alternative 2 - baseline}}$	+ $2,356
$P_{8\,\text{alternative 2 - baseline}}$	- $50,151
$P_{9\,\text{alternative 2 - baseline}}$	+ $2,985
$P_{10\,\text{alternative 2 - baseline}}$	0
$P_{11\,\text{alternative 2 - baseline}}$	+ $4,468 - $933,977
$P_{12\,\text{alternative 2 - baseline}}$	Not availabe (Assume 25K)

Table 11

Analysis of Alternative Structure 1 vs. Alternative Structure 2 for Fort Benning-DEH

$P_{1_{\text{alternative 1 - alternative 2}}}$	+ $1,094
$P_{2_{\text{alternative 1 - alternative 2}}}$	+ $5,203
$P_{3_{\text{alternative 1 - alternative 2}}}$	+ $84,931
$P_{4_{\text{alternative 1 - alternative 2}}}$	+ $870,629
$P_{5_{\text{alternative 1 - alternative 2}}}$	- $318
$P_{6_{\text{alternative 1 - alternative 2}}}$	- $16,966
$P_{7_{\text{alternative 1 - alternative 2}}}$	+ $2,736
$P_{8_{\text{alternative 1 - alternative 2}}}$	+ $39,989
$P_{9_{\text{alternative 1 - alternative 2}}}$	0
$P_{10_{\text{alternative 1 - alternative 2}}}$	- $553
$P_{11_{\text{alternative 1 - alternative 2}}}$	- $1,097 + $985,648
$P_{12_{\text{alternative 1 - alternative 2}}}$	Not available (Assume 25K)

Table 12

Total Annual Benefits of the Alternatives

Total annual benefits of choosing alternative structure 1 over alternative structure 2 at Fort Benning	+ $985,648
Total annual benefits of choosing alternative structure 1 over the existing structure at Fort Benning	+ $44,807
Total annual benefits of choosing alternative structure 2 over the existing structure at Fort Benning	- $933,977

4 CONCLUSIONS AND RECOMMENDATIONS

The primary factor influencing vehicle maintenance responsiveness was found to be turnaround time, which in turn is influenced by workload, available workforce, maintenance priorities, the parts ordering process, and organizational structure. Responsiveness and productivity parameters related to these factors were developed and used to build a model for determining the optimal performance structure at a given installation.

An example application of the model made for vehicle maintenance operations at Fort Benning, GA, showed that consolidating vehicle maintenance under

1. the DIO would result in a disbenefit to the Army of $933,977 annually relative to the existing structure,

2. the DEH would result in an annual savings to the Army of $985,648 relative to consolidation under the DIO,

3. the DEH would result in an annual savings to the Army of $44,807 over the existing structure.

It is recommended that

1. USA-CERL researchers develop detailed specifications of data required for use of the model, so individual installations can collect the data necessary to perform their own analysis.

2. Further work be undertaken on enhancing the decision-making model. For example, construct a ratio, R, which is a function of the parameters, and approximate the distribution of the statistics developed so that a "band of indifference" can be incorporated into the use of the model. By doing this, one can develop for each installation at which the model is used constant terms A and B that allow for the model to be "indecisive"; i.e., at a particular installation, if $A \leq R \leq B$, then no decision can be made according to some confidence level determined beforehand.

The specific recommendation for Fort Benning, based on results of the model analysis, is to consolidate vehicle maintenance functions under the DEH. This would significantly increase responsiveness of the DEH vehicle maintenance organization and provide savings to the Army sufficient to recover the cost of upgrading DEH facilities, equipment, and tools in less than a year.

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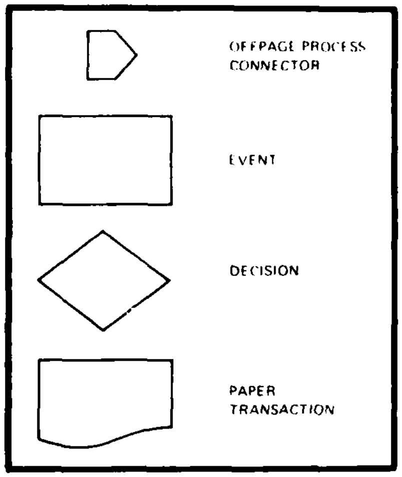
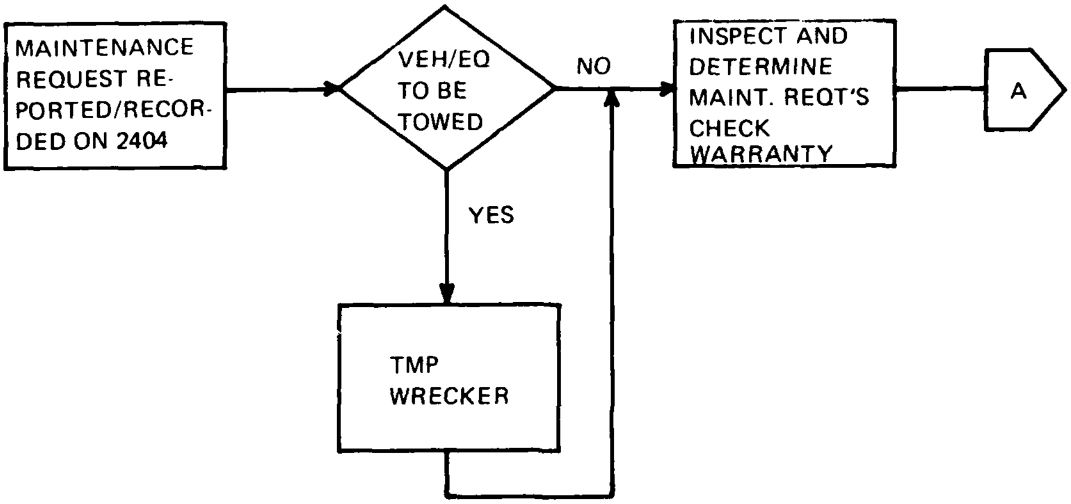
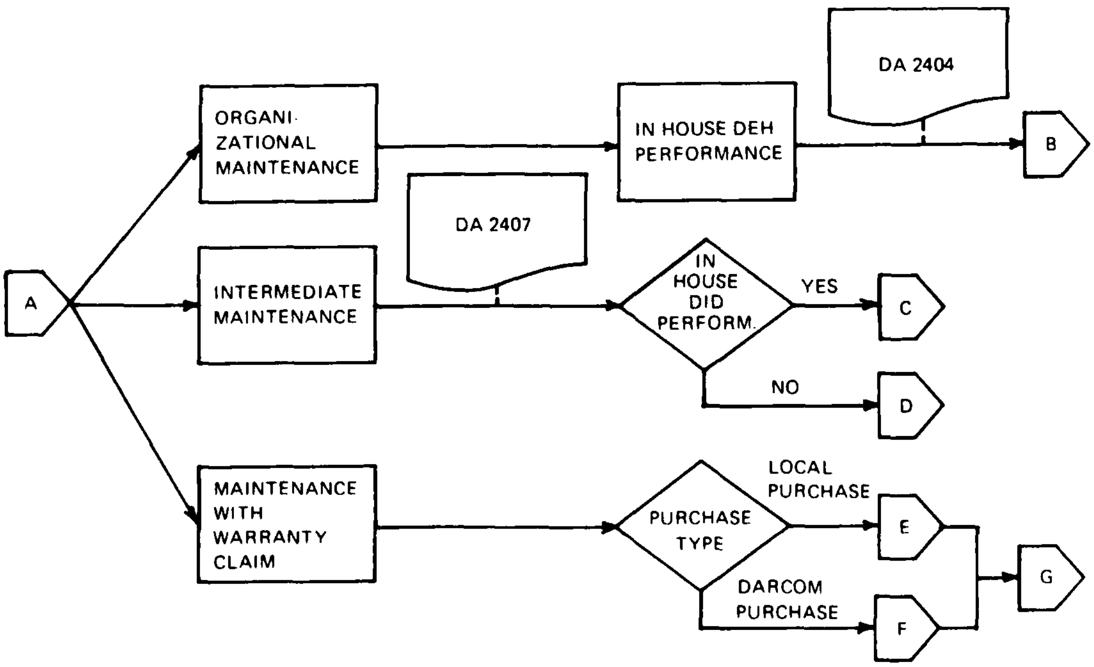
APPENDIX A:

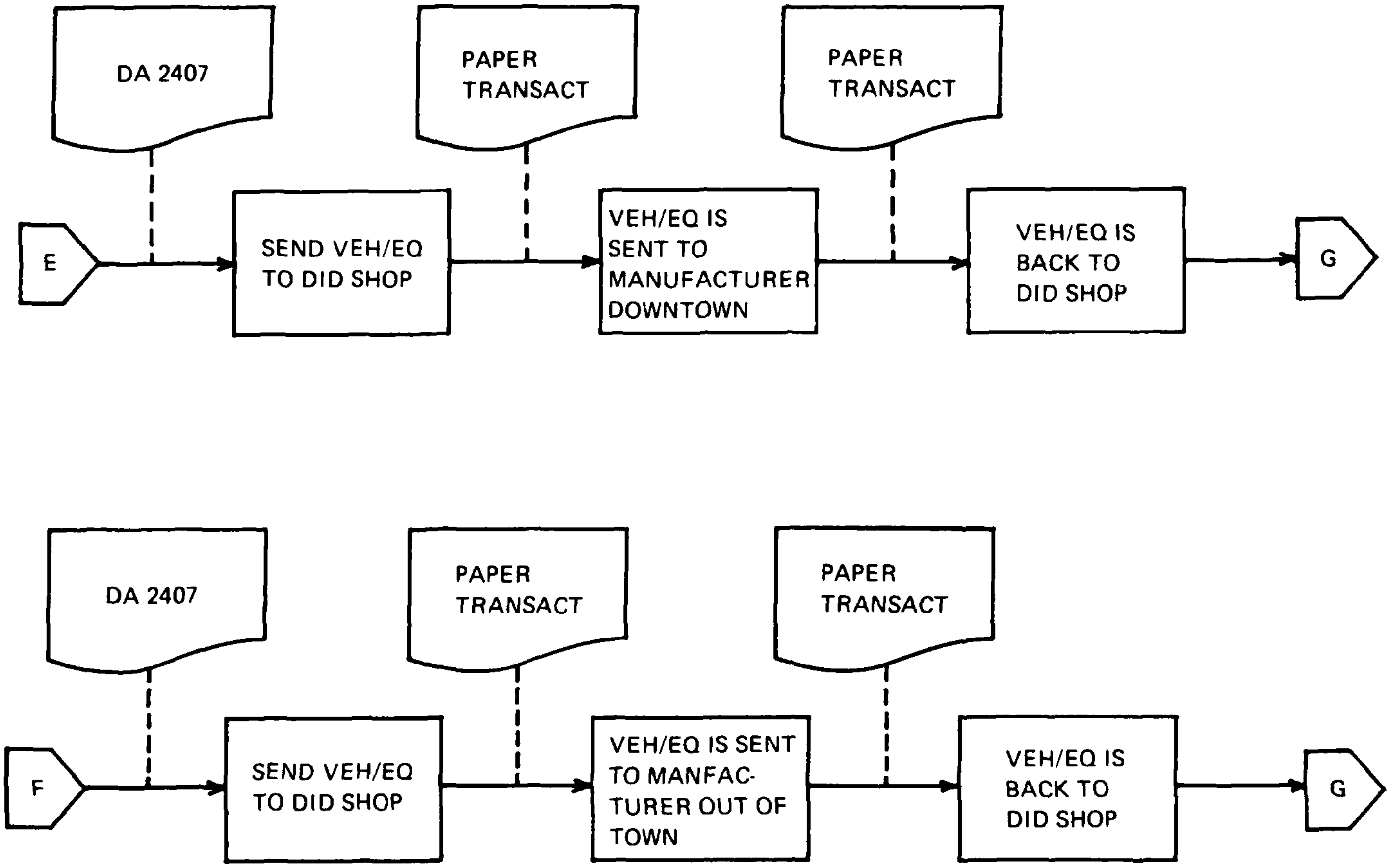
VEHICLE MAINTENANCE PROCESS FLOW CHART FOR THE BASELINE STRUCTURE

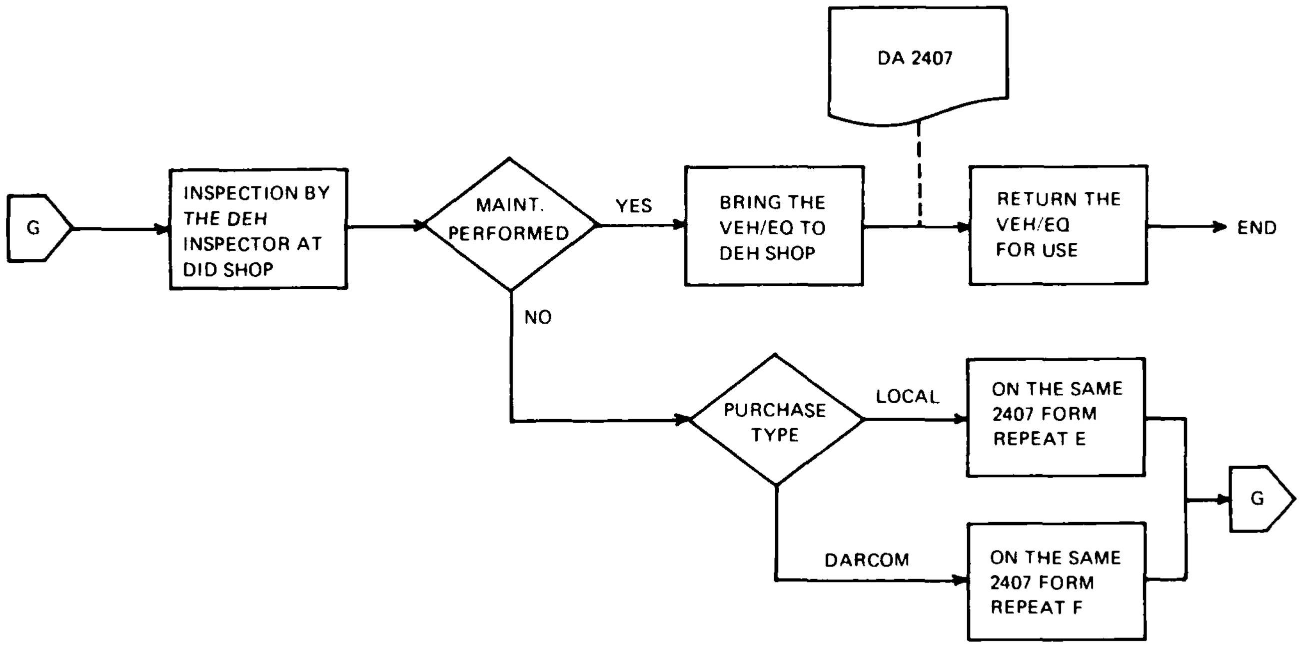
LEGEND

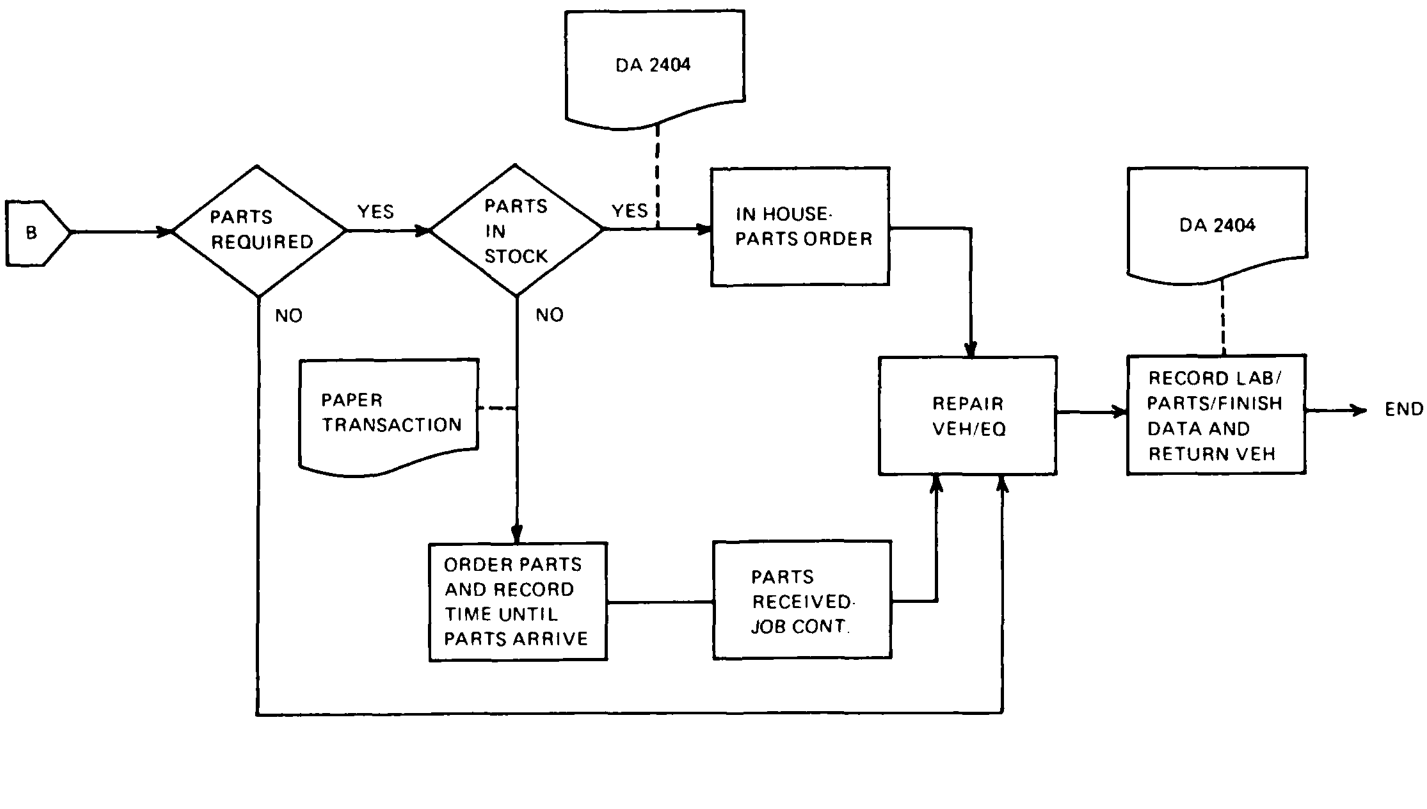


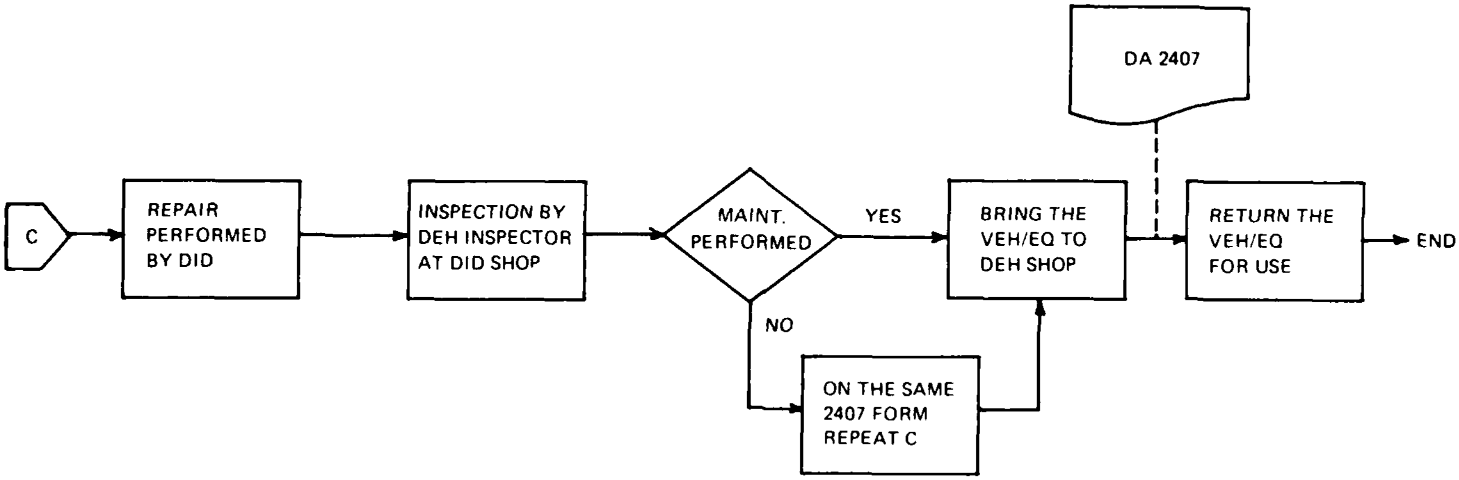


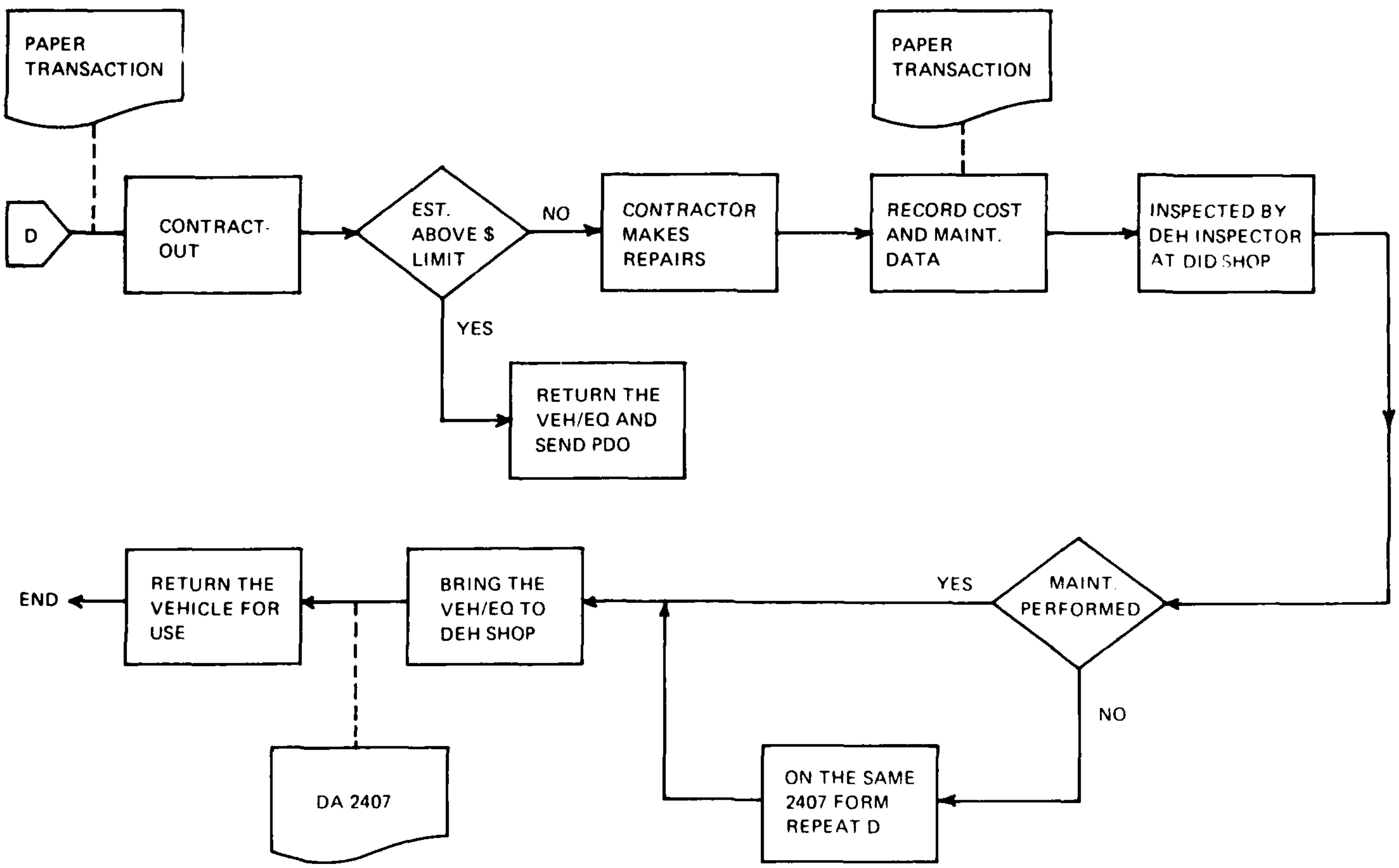



DA 2407
PAPER TRANSACT
PAPER TRANSACT
E
SEND VEH/EQ TO DID SHOP
VEH/EQ IS SENT TO MANUFACTURER DOWNTOWN
VEH/EQ IS BACK TO DID SHOP
G
DA 2407
PAPER TRANSACT
PAPER TRANSACT
F
SEND VEH/EQ TO DID SHOP
VEH/EQ IS SENT TO MANFAC-TURER OUT OF TOWN
VEH/EQ IS BACK TO DID SHOP
G


G
INSPECTION BY THE DEH INSPECTOR AT DID SHOP
MAINT. PERFORMED
YES
NO
BRING THE VEH/EQ TO DEH SHOP
DA 2407
RETURN THE VEH/EQ FOR USE
END
PURCHASE TYPE
LOCAL
DARCOM
ON THE SAME 2407 FORM REPEAT E
ON THE SAME 2407 FORM REPEAT F
G


B
PARTS REQUIRED
YES
NO
PARTS IN STOCK
YES
NO
DA 2404
IN HOUSE-PARTS ORDER
PAPER TRANSACTION
ORDER PARTS AND RECORD TIME UNTIL PARTS ARRIVE
PARTS RECEIVED-JOB CONT.
REPAIR VEH/EQ
DA 2404
RECORD LAB/PARTS/FINISH DATA AND RETURN VEH
END


C
REPAIR PERFORMED BY DID
INSPECTION BY DEH INSPECTOR AT DID SHOP
MAINT. PERFORMED
YES
NO
BRING THE VEH/EQ TO DEH SHOP
DA 2407
RETURN THE VEH/EQ FOR USE
END
ON THE SAME 2407 FORM REPEAT C


PAPER TRANSACTION
D
CONTRACT-OUT
EST. ABOVE $ LIMIT
NO
YES
CONTRACTOR MAKES REPAIRS
PAPER TRANSACTION
RECORD COST AND MAINT. DATA
INSPECTED BY DEH INSPECTOR AT DID SHOP
RETURN THE VEH/EQ AND SEND PDO
MAINT. PERFORMED
YES
NO
BRING THE VEH/EQ TO DEH SHOP
RETURN THE VEHICLE FOR USE
END
DA 2407
ON THE SAME 2407 FORM REPEAT D

APPENDIX B:

DEVELOPMENT OF MATHEMATICAL FORMULAS FOR MODEL PARAMETERS

B.1 Determination of Parameter P_1

P_1 = Annual cost of intermediate level maintenance cases

$$P_1 = (a_1) \times (n_1) \times (e_1)$$

where

a_1 = Average man-hours involved for intermediate level maintenance cases

n_1 = Number of intermediate level maintenance cases per year

e_1 = Effective shop labor rate of the organization performing intermediate maintenance.

r = number of wage grades

Define e_1 as follows:

$$e_1 = \begin{pmatrix}\text{average}\\ \text{labor cost}\\ \text{per hour}\end{pmatrix} \left[1 + \begin{pmatrix}\text{administrative}\\ \text{overhead}\\ \text{cost (\%)}\end{pmatrix} + \begin{pmatrix}\text{operational}\\ \text{overhead}\\ \text{cost (\%)}\end{pmatrix} \right]$$

where

$$\begin{matrix}\text{average}\\ \text{labor cost}\\ \text{per hour}\end{matrix} = \frac{\sum_{i=1}^{r} \begin{pmatrix}\text{Hourly}\\ \text{wage grade}_i\end{pmatrix} \begin{pmatrix}\text{Number of}\\ \text{mechanics of}\\ \text{wage grade}_i\end{pmatrix}}{\text{Total \# of mechanics}}$$

B.2 Determination of Parameter P_2

P_2 = Annual cost of organizational maintenance cases

$$P_2 = (a_2) \times (n_2) \times (e_2)$$

where

a_2 = Average man-hours involved for organizational maintenance cases

n_2 = Number of organizational maintenance cases per year

e_2 = Effective shop labor rate of the organization performing organizational maintenance (e_2 is determined the same way the term e_1 is determined. See Paragraph B.1.)

B.3 Determination of Parameter $P_{3_{b-a}}$

$P_{3_{b-a}}$ = Annual cost difference related to the change in DEH inventory for intermediate maintenance cases due to choosing alternative b over alternative a.

Let

V_{3_a} = Total DEH inventory under alternative a

V_{3_b} = Total DEH inventory under alternative b

D = Total available vehicle days
(Total days available/year) x (number of vehicles)

U_{3_a} = Utilization under alternative a

U_{3_b} = Utilization under alternative b

A_{3_a} = Average turnaround time (in days) for intermediate maintenance cases under alternative a

A_{3_b} = Average turnaround time (in days) for intermediate maintenance cases under alternative b

T_{3_a} = Total vehicle days down for intermediate maintenance cases under alternative a

T_{3_b} = Total vehicle days down for intermediate maintenance cases under alternative b

$$T_{3_b} = \frac{A_{3_b}}{A_{3_a}} \cdot T_{3_a} \text{ and } U_{3_b} - U_{3_a} = (D - T_{3_b}) - (D - T_{3_a}) = T_{3_a} - T_{3_b}$$

$$V_{3_b} = \left(1 - \frac{T_{3_a} - T_{3_b}}{D}\right) V_{3_a}$$

$$\frac{V_{3_b}}{V_{3_a}} = \left(1 - \frac{T_{3_a} - T_{3_b}}{D}\right)$$

$$P_{3_{b-a}} = \left(\frac{T_{3_a} - T_{3_b}}{D}\right) \left(\begin{array}{l}\text{Present value of the} \\ \text{DEH inventory under alternative a}\end{array}\right)$$

B.4 Determination of Parameter $P_{4_{b-a}}$

$P_{4_{b-a}}$ = Annual cost difference related to the change in DEH inventory for organizational maintenance cases due to choosing alternative b over alternative a.

Let

V_{4_a} = Total DEH inventory under alternative a (same as V_{3_a})

V_{4_b} = Total DEH inventory under alternative b

D = Total available vehicle days
(Total days available/year) x (number of vehicles)

U_{4_a} = Utilization under alternative a

U_{4_b} = Utilization under alternative b

A_{4_a} = Average turnaround time (in days) for organizational maintenance cases under alternative a

A_{4_b} = Average turnaround time (in days) for organizational maintenance cases under alternative b

T_{4_a} = Total vehicle days down for organizational maintenance cases under alternative a

T_{4_b} = Total vehicle days down for organizational maintenance cases under alternative b

$$T_{4_b} = \frac{A_{4_b}}{A_{4_a}} \cdot T_{4_a} \quad \text{and} \quad U_{4_b} - U_{4_a} = (D - T_{4_b}) - (D - T_{4_a}) = T_{4_a} - T_{4_b}$$

$$V_{4_b} = \left(1 - \frac{T_{4_a} - T_{4_b}}{D}\right) V_{4_a} \rightarrow$$

$$\frac{V_{4_b}}{V_{4_a}} = \left(1 - \frac{T_{4_a} - T_{4_b}}{D}\right)$$

$$P_{4_{b-a}} = \left(\frac{T_{4_a} - T_{4_b}}{D}\right) \left(\begin{array}{l}\text{Present value of the} \\ \text{DEH inventory under alternative a}\end{array}\right)$$

B.5 Determination of Parameter $P_{5_{b-a}}$

$P_{5_{b-a}}$ = Annual intermediate maintenance cost difference related to the change in utilization due to choosing alternative b over alternative a.

$$P_{5_{b-a}} = \left[1 - \frac{1}{\left(1 - \frac{T_{3_a} - T_{3_b}}{D}\right)}\right] P_1$$

where P_1 is the same term defined in Paragraph B.1; and T_{3_a}, T_{3_b}, D are the same terms defined in Paragraph B.3.

B.6 Determination of Parameter $P_{6_{b-a}}$

$P_{6_{b-a}}$ = Annual organizational maintenance cost difference related to the change in utilization due to choosing alternative b over alternative a.

$$P_{6_{b-a}} = \left[1 - \frac{1}{\left(1 - \frac{T_{4_a} - T_{4_b}}{D}\right)}\right] P_2$$

where P_2 is the same term defined in paragraph B.2; and T_{4_a}, T_{4_b}, D are the same terms defined in Paragraph B.4.

B.7 Determination of Parameter P_7

P_7 = Annual inspection cost of intermediate maintenance cases

$P_7 = (t_1) \times (n_1) \times (e_3)$

where

t_1 = Average time spent for the inspection of an intermediate maintenance case.

n_1 = Number of intermediate maintenance cases per year.

e_3 = Effective shop labor rate of the organization(s) performing inspection(s) for intermediate maintenance cases. (e_3 is defined the same way the term e is defined. See Paragraph B.1.)

B.8 Determination of Parameter P_8

P_8 = Annual inspection cost of organizational maintenance cases.

$P_8 = (t_2) \times (n_2) \times (e_4)$

where

t_2 = Average time spent for the inspection of an organizational maintenance case.

n_2 = Number of organizational maintenance cases per year.

e_4 = Effective shop labor rate of the organization performing organizational maintenance (same as e_2)

B.9 Determination of Parameter P_9

P_9* = Annual transportation cost of a vehicle for intermediate maintenance cases.

$P_9 = (t_3) \times (n_1) \times (e_5)$

where

t_3 = Average time spent for transporting a vehicle from DEH shop to DIO and returning back to DEH after repair.

n_1 = Number of intermediate maintenance cases per year.

e_5 = Effective shop labor rate of the DEH maintenance shop. (e_4 is defined the same way the term e_1 is defined. See Paragraph B.1.)

*This parameter exists only in the case of baseline structure. P_9 for alternative structures 1 and 2 is zero.

B.10 Determination of Parameter P_{10}

P_{10} = Annual cost associated with the parts ordering process for intermediate maintenance cases.

$P_{10} = (t_4) \times (n_1) \times (e_6)$

where

t_4 = Average time spent for ordering parts for intermediate maintenance cases.

n_1 = Number of intermediate maintenance cases per year.

e_6 = Effective shop labor rate for the organization performing the intermediate maintenance (same as e_1).

B.11 Determination of Parameter P_{11}

P_{11} = Annual cost associated with the parts ordering process for organizational maintenance cases.

$P_{11} = (t_5) \times (n_2) \times (e_7)$

where

t_5 = Average time spent for ordering parts for organization maintenance cases.

n_2 = Number of organizational maintenance cases per year.

e_7 = Effective shop labor rate for the organization performing organizational maintenance (same as e_2).

B.12 Determination of Parameter P_{12}

P_{12} = Total estimated cost of upgrading the maintenance facility when choosing the optimal alternative.

P_{12} includes the cost of buying new tools, equipment, upgrading the maintenance shop, hiring more mechanics (whichever factors apply).

APPENDIX C:

DETERMINATION OF PARAMETERS FOR FORT BENNING DEH WHEN COMPARING ALTERNATIVE STRUCTURE 1 WITH THE BASELINE STRUCTURE

C.1 Calculation of $P_{1_{b-a}}$

P_{1_a} = Annual cost of intermediate level maintenance cases at Fort Benning under the existing structure (baseline).

$P_{1_a} = (a_{1_a}) \times (n_{1_a}) \times (e_{1_a})$

a_{1_a} = Average manhours involved for intermediate level maintenance cases at Fort Benning under the existing structure = 33.50 hours.

n_{1_a} = Number of intermediate level maintenance cases per year at Fort Benning = 171 ÷ 2 = 86.

e_{1_a} = Effective shop labor rate for Fort Benning under the existing structure = \$11.57

P_{1_a} = (33.50)(86)(11.57) = \$33,333.17

P_{1_b} = Annual cost of intermediate level maintenance cases at Fort Benning under the existing structure (baseline).

$P_{1_b} = (a_{1_b}) \times (n_{1_b}) \times (e_{1_b})$

a_{1_b} = Average manhours involved for intermediate level maintenance cases at Fort Benning (same as a_{1_a}) = 33.50 hours.

n_{1_b} = Number of intermediate level maintenance cases per year at Fort Benning (same as n_{1_a}) = 171 ÷ 2 = 86.

e_{1_b} = Estimated effective shop labor rate if Fort Benning was alternative structure 1 = \$13.42

P_{1_b} = (33.50)(86)(13.42) = \$38,663.02

$P_{1_{b-a}}$ = Annual cost difference for intermediate level maintenance cases when choosing alternative structure 1 over the baseline structure at Fort Benning.

$P_{1_{b-a}} = P_{1_a} - P_{1_b}$ = -\$5329.85

C.2 Calculation of $P_{2_{b-a}}$

P_{2_a} = Annual cost of organizational level maintenance cases under the existing structure (baseline) at Fort Benning.

$P_{2_a} = (a_{2_a}) \times (n_{2_a}) \times (e_{2_a})$

a_{2_a} = Average manhours involved for organizational maintenance cases at Fort Benning under the existing structure = 3.739 hours.

n_{2_a} = Number of organizational maintenance cases per year at Fort Benning = 7324 ÷ 2 = 3662.

e_{2_a} = Effective shop labor rate of Fort Benning under the existing structure (same as e_{1_a}) = \$11.57.

$P_{2_a} = (3.739)(3662)(11.57) = \$158,418.96$

P_{2_b} = Annual cost of organizational level maintenance cases if Fort Benning was alternative structure 1.

$P_{2_b} = (a_{2_b}) \times (n_{2_b}) \times (e_{2_b})$

a_{2_b} = Average manhours involved for organizational maintenance cases at Fort Benning (same as a_{2_a}) = 3.739 hours.

n_{2_b} = Number of organizational maintenance cases per year at Fort Benning (same as n_{1_a}) = 7324 ÷ 2 = 3662.

e_{2_b} = Estimated effective shop labor rate of Fort Benning was alternative structure 1 = \$13.42.

$P_{2_b} = (3.739)(3662)(13.42) = \$183,749.57$

$P_{2_{b-a}}$ = Annual cost difference for organizational level maintenance cases when choosing alternative structure 1 over the baseline at Fort Benning.

$P_{2_{b-a}} = P_{2_a} - P_{2_b} = -\$25,330.61$

C.3 Calculation of P_3

$P_{3_{b-a}}$ = Annual cost difference related to the change in DEH inventory for intermediate mainenance cases due to choosing alternative structure 1 over the existing structure (baseline) at Fort Benning.

$$P_{3_{b-a}} = \left(\frac{T_{3_a} - T_{3_b}}{D}\right)\left(\begin{array}{l}\text{Present value of the}\\ \text{DEH inventory at Fort Benning}\\ \text{under the existing structure}\end{array}\right)$$

D = Total available vehicle days per year = (1184 vehicles) x (260 days) = 307,840

T_{3_a} = Total vehicle days down per year for intermediate maintenance cases under the existing structure at Fort Benning = (45.2868) (171 ÷ 2) = 3872.02 vehicle days.

T_{3_b} = Total vehicle days down per year for intermediate maintenance cases if Fort Benning was alternative structure 1.

$$T_{3_b} = \left(\frac{A_{3_b}}{A_{3_a}}\right) \cdot T_{3_a} \text{ where}$$

A_{3_b} = Average turnaround time (in days) for intermediate maintenance cases if Fort Benning was alternative structure 1.

A_{3_a} = Average turnaround time (in days) for intermediate maintenance cases at Fort Benning under the existing structure = 45.2868.

The term A_{3_b} will be estimated as follows:

Define a term called VEPE - Vehicle Equivalents Per Employee - to be:

$$\text{VEPE} = \frac{\text{Number of total vehicle equivalents}}{\text{Number of total employees}}$$

and also define Employees Per Vehicle Equivalent (EPVE) to be:

$$\text{EPVE} = \frac{1}{\text{VEPE}}$$

Furthermore, the following equation is defined assuming that at each installation types of vehicles are similar, complexity of maintenance is similar, and the employees have similar qualifications to perform similar maintenance cases:

$$\begin{pmatrix}\text{Turnaround time}\\ \text{at installation-x}\end{pmatrix} \begin{pmatrix}\text{EPVE for}\\ \text{installation-x}\end{pmatrix} = \begin{pmatrix}\text{Turnaround time}\\ \text{at installation-y}\end{pmatrix} \begin{pmatrix}\text{EPVE for}\\ \text{installation-y}\end{pmatrix}$$

Using above equation for our specific case, we obtain:

$$A_{3_b} = \frac{\begin{pmatrix}\text{weighted average of EPVE}\\ \text{at Fort Dix and Fort Lewis}\end{pmatrix} \begin{pmatrix}\text{weighted average of}\\ \text{turnaround time for intermediate}\\ \text{cases at Fort Dix and Fort Lewis}\end{pmatrix}}{(\text{EPVE for Fort Benning})}$$

$$A_{3_b} = \frac{(0.01425)(17.68)}{(0.22262)} = 11.31$$

$$T_{3_b} = \frac{11.31}{45.287} \quad (3872.02) = 967 \text{ vehicle days}$$

$$T_{3_a} - T_{3_b} = 3872.02 - 967 = 2905.02 \text{ vehicle days}$$

(Hence, if Fort Benning was alternative structure 1 total vehicle days down for intermediate cases would be reduced 2905.02 vehicle days per year.)

$$P_{3_{b-a}} = \left(\frac{T_{3_a} - T_{3_b}}{D}\right)\left(\begin{array}{l}\text{Present value of}\\ \text{DEH inventory}\end{array}\right)$$

$$P_{3_{b-a}} = \frac{2905.02 \text{ vehicle days}}{(1184 \text{ vehicles})(260 \text{ days})} \quad (\$9{,}000{,}000)$$

$$P_{3_{b-a}} = \$84{,}931$$

C.4 Calculation of $P_{4_{b-a}}$

$P_{4_{b-a}}$ = Annual cost difference related to the change in DEH inventory for organizational maintenance costs due to choosing alternative structure 1 over the existing structure (baseline) at Fort Benning.

$$P_{4_{b-a}} = \left(\frac{T_{4_a} - T_{4_b}}{D}\right)\left(\begin{array}{l}\text{Present value of the DEH}\\ \text{inventory at Fort Benning}\\ \text{under the existing structure}\end{array}\right)$$

T_{4_b} = Total vehicle days down for organizational maintenance cases if Fort Benning was alternative structure 1.

T_{4_a} = Total vehicle days down for organizational maintenance cases under the existing structure at Fort Benning.

We assume that $T_{4_a} = T_{4_b}$ since under both alternatives organizational maintenance is performed by DEH.

Since $T_{4_a} = T_{4_b}$, $T_{4_a} - T_{4_b} = 0$, hence $P_{4_{b-a}} = 0$.

C.5 Calculation of $P_{5_{b-a}}$

$P_{5_{b-a}}$ = Annual intermediate maintenance cost difference related to the change in utilization due to choosing alternative structure 1 over the existing structure (baseline) at Fort Benning.

$$P_{5_{b-a}} = \left[1 - \frac{1}{\left(1 - \frac{T_{3_a} - T_{3_b}}{D}\right)}\right] P_{1_a}$$

$$P_{5_{b-a}} = \left(1 - \frac{1}{1 - \frac{2905.02}{307840}}\right)(33333.17)$$

$$P_{5_{b-a}} = \left(1 - \frac{1}{1-.009436}\right)(33333.17)$$

$$= \left(1 - \frac{1}{.99056}\right)(33333.7) = -\$317.56$$

C.6 Calculation of $P_{6_{b-a}}$

$P_{6_{b-a}}$ = Annual organizational maintenance cost difference related to the change in utilization due to choosing alternative structure 1 over the existing structure at Fort Benning.

$$P_{6_{b-a}} = \left[1 - \frac{1}{\left(1 - \frac{T_{4_a} - T_{4_b}}{D}\right)}\right] P_{2_a}$$

$$P_{6_{b-a}} = \left(1 - \frac{1}{1 - 0}\right) P_{2_a}$$

(since $T_{4_a} - T_{4_b} = 0$)

$$P_{6_{b-a}} = (1 - 1)\, P_{2_a} = 0$$

C.7 Calculation of $P_{7_{b-a}}$

P_{7_a} = Annual inspection cost of the intermediate maintenance cases at Fort Benning under the existing structure (baseline).

P_{7_a} = $(t_{1_a})(n_1)(e_{3_a})$

t_{1_a} = Average time spent for the inspection of the intermediate maintenance cases at Fort Benning under the existing structure. (It includes inspection time at DEH and DIO) = 2 hours (DEH inspection) + 2 3/4 hours (DIO initial inspection) + 1 1/2 hours (DIO final inspection) = 6 1/4 hours

e_{3_b} = Effective shop labor rate.

n_1 = Number of intermediate maintenance cases per year at Fort Benning = (171 ÷ 2) = 86.

P_{7_a} = [(\$11.57/hr)(2) + (\$14.80/hr)(4 1/4)](86) = 7399.44

P_{7_a} = 7399.44

DEH effective shop labor rate (current): \$11.57/hr

DIO effective shop labor rate (current): \$13.80/hr

P_{7_b} = Annual inspection cost of the intermediate maintenance cases at Fort Benning if it was alternative structure 1.

$P_{7_b} = (t_{1_b})(n_1)(e_{3_b})$

t_{1_b} = Estimate average time spent for the inspection of an intermediate maintenance case = 2 hours.

n_1 = Number of intermediate maintenance cases per year at Fort Benning = $(171 \div 2) = 86$.

e_3 = Estimated effective shop labor rate of Fort Benning if it was alternative structure 1 = \$13.42.

$P_{7_b} = (2)(86)(13.42) = \$2308.24$

$P_{7_{b-a}}$ = Annual inspection cost difference for the intermediate maintenance cases at Fort Benning when choosing alternative structure 1 over the existing structure (baseline).

$P_{7_{b-a}} = P_{7_a} - P_{7_b} = \$7399.44 - \$2308.24 = \$5091.20.$

C.8 Calculation of $P_{8_{b-a}}$

P_{8_a} = Annual inspection cost of the organizational maintenance cases at Fort Benning under the existing structure.

$P_{8_a} = (t_{2_a})(n_2)(e_4)$

t_{2_a} = Average time spent for the inspection of an organizational maintenance case at Fort Benning under the existing structure (same as t_{2_b}) = 1.5 hours.

n_2 = Number of organizational maintenance cases per year at Fort Benning = 3662

e_4 = Effective shop labor rate at Fort Benning (current) = \$11.57

$P_{8_a} = (1.5)(3662)(11.57) = \$63554.01$

P_{8_b} = Annual inspection cost of the organizational maintenance cases at Fort Benning under alternative structure 1.

$P_{8_b} = (t_{2_b})(n_2)(e_4)$

t_{2_b} = Estimated average time spent for the inspection of an organizational maintenance case under alternative structure 1 = 1.5 hours.

n_2 = Number of organizational maintenance cases per year at Fort Benning = 7324 ÷ = 3662

e_4 = Estimate effective shop labor rate if Fort Benning was alternative structure 1 = \$13.42.

P_{8_b} = (1.5)(3662)(13.42) = \$73716.06

$P_{8_{b-a}}$ = Annual inspection cost difference for the organizational maintenance cases at Fort Benning when choosing alternative structure 1 over the existing structure.

$P_{8_{b-a}} = P_{8_a} - P_{8_b}$ = \$63554.01 - \$73716.06 = -\$10162.05

C.9 <u>Calculation of $P_{9_{b-a}}$</u>

P_{9_a} = Annual transportation cost of a vehicle for intermediate maintenance cases at Fort Benning under the existing structure.

$P_{9_a} = (t_{3_a})(n_1)(e_5)$

t_3 = Estimated average time spent for transporting a vehicle from DEH shop to DIO and returning back to DEH after repair for an intermediate maintenance case at Fort Benning = 3 hours.

n_1 = Number of intermediate maintenance cases per year at Fort Benning = 86.

e_4 = Effective shop labor rate of the DEH shop at Fort Benning = \$11.57

P_{9_a} = (3)(86)(11.57) = \$2985.06

P_{9_b} = 0 (since $t_{3_b} = 0$)

P_{9_c} = 0 (since $t_{3_c} = 0$)

$P_{9_{b-a}}$ = Annual transportation cost difference for intermediate maintenance cases at Fort Benning when choosing alternative 1 over existing structure.

$P_{9_{b-a}} = P_{9_a} - P_{9_b}$ = \$2985.06 - 0 = \$2985.06

C.10 Calculation of $P_{10_{b-a}}$

P_{10_a} = Annual cost associated with the parts ordering process for intermediate maintenance at Fort Benning under the existing structure.

P_{10_a} = $(t_{4_a})(n_1)(e_6)$

t_{4_a} = Average time spent for parts ordering process for an intermediate maintenance case at Fort Benning under the existing structure (same as t_{4_b}) - 3/4 hours.

n_1 = Number of intermediate maintenance cases per year at Fort Benning = 86.

e_6 = Effective shop labor rate of the DIO shop at Fort Benning (current) = \$13.80.

P_{10_a} = (3/4)(86)(13.80) = \$890.10

P_{10_b} = Annual cost associated with the parts ordering process for intermediate maintenance cases if Fort Benning was alternative structure 1.

P_{10_b} = $(t_{4_b})(n_1)(e_6)$

t_{4_b} = Estimated average time for parts ordering process for an intermediate maintenance case at Fort Benning under alternative structure 1 = 1 1/4 hours.

n_1 = Number of intermediate maintenance cases per year = 86.

e_6 = Estimated effective shop labor rate if Fort Benning was alternative structure 1 = \$13.42.

P_{10_b} = (1 1/4)(86)(13.42) = \$1442.65

$P_{10_{b-a}}$ = Annual cost difference associated with the parts ordering process for intermediate maintenance costs at Fort Benning when choosing alternative 1 over the existing structure.

$P_{10_{b-a}}$ = $P_{10_a} - P_{10_b}$ = \$890.10 - \$1442.65 = -\$552.58

C.11 Calculation of $P_{11_{b-a}}$

P_{11_a} = Annual cost associated with the parts ordering process for organizational maintenance cases at Fort Benning under the existing structure.

P_{11_a} = $(t_{5_a})(n_2)(e_7)$

t_{5_a} = Average time spent for parts ordering process for an organizational maintenance case at Fort Benning under the existing structure (same as t_{5_b}) = 1 hour.

n_2 = Number of organizational maintenance cases per year at Fort Benning = 3662.

e_7 = Effective shop labor rate at Fort Benning = \$11.57.

P_{11_a} = (1)(3662)(11.57) = 42369.34.

P_{11_b} = Annual cost associated with the parts ordering process for organizational maintenance cases at Fort Benning under alternative 1.

$P_{11_b} = (t_{5_b})(n_2)(e_7)$

t_{5_b} = Average time spent for parts ordering process for an organizational maintenance case at Fort Benning under alternative 1 = 1 hour.

n_2 = Number of organizational maintenance cases per year at Fort Benning = 3662.

e_7 = Estimated effective shop labor rate at Fort Benning under alternative 1 = \$13.42.

P_{11_b} = (1)(3662)(13.42) = \$48875.64

$P_{11_{b-a}}$ = Annual cost difference associated with the parts ordering process for organizational maintenance cases at Fort Benning when choosing alternative 1 over the existing structure.

$P_{11_{b-a}} = P_{11_a} - P_{11_b}$ = \$42369.34 - \$48875.64 = -\$6506.30

APPENDIX D:

DETERMINATION OF PARAMETERS FOR FORT BENNING DEH WHEN COMPARING ALTERNATIVE STRUCTURE 2 WITH THE BASELINE STRUCTURE

D.1 Calculation of $P_{1_{c-a}}$

P_{1_c} = Annual cost of intermediate level maintenance cases at Fort Benning if Fort Benning was alternative structure 2.

$P_{1_c} = (a_{1_c})(n_{1_c})(e_{1_c})$

a_{1_c} = Average manhours involved for intermediate level maintenance cases at Fort Benning if Fort Benning was alternative structure 2 (same as a_{1_a}) = 33.50 hours.

n_{1_c} = Number of intermediate level maintenance cases (same as n_{1_a}) = 171 ÷ 2 = 86.

e_{1_c} = Estimated effective shop labor rate if Fort Benning was alternative structure 2 (use the current DIO effective shop labor rate at Fort Benning) = \$13.80.

P_{1_c} = (33.50)(86)(13.80) = \$39757.80

$P_{1_{c-a}}$ = Annual cost difference for intermediate level maintenance cases when choosing alternative structure 2 over the baseline structure at Fort Benning.

$P_{1_{c-a}} = P_{1_a} - P_{1_c}$ = -\$6424.63

(For P_{1_a}, see paragraph C.1.)

D.2 Calculation of $P_{2_{c-a}}$

P_{2_c} = Annual cost of organizational level maintenance cases if Fort Benning was alternative structure 2.

$P_{2_c} = (a_{2_c})(n_{2_c})(e_{2_c})$

a_{2_c} = Average manhours involved for organizational maintenance cases at Fort Benning (same as a_{2_a}) = 3.739 hours.

n_{2_c} = Number of organizational maintenance cases per year at Fort Benning (same as n_{2_a}) = 7324 ÷ 2 = 3662.

e_{2_c} = Estimated effective shop labor rate if Fort Benning was alternative structure 2 (current DIO rate at Fort Benning) = \$13.80.

P_{2_c} = (3.739)(3663)(13.80) = \$188952.61.

$P_{2_{c-a}}$ = Annual cost difference for organizational level maintenance cases when choosing alternative structure 2 over the baseline at Fort Benning.

$$P_{2_{c-a}} = P_{2_a} - P_{2_c} = -\$30,533.65.$$

(For P_{2_a}, see paragraph C.2.)

D.3 Calculation of $P_{3_{c-a}}$

$P_{3_{c-a}}$ = Annual cost difference related to the change in DEH inventory for intermediate maintenance cases due to choosing alternative structure 2 over the existing structure (baseline) at Fort Benning.

$$P_{3_{c-a}} = \left(\frac{T_{3_c} - T_{3_a}}{D}\right)\left(\text{Present value of the DEH inventory at Fort Benning under the existing structure}\right)$$

D = Total available vehicle days per year.

T_{3_a} = Total vehicle days down for intermediate maintenance cases under the existing structure at Fort Benning.

T_{3_c} = Total vehicle days down for intermediate maintenance cases if Fort Benning was alternative structure 2.

We assume that $T_{3_a} = T_{3_c}$ since under both alternatives DIO does the intermediate maintenance.

Since $T_{3_a} - T_{3_c}$, $T_{3_c} - T_{3_a} = 0$. Hence $P_{3_{c-a}} = 0$.

D.4. Calculation of $P_{4_{c-a}}$

$P_{4_{c-a}}$ = Annual cost difference related to the change in DEH inventory for organizational maintenance cases due to choosing alternative structure 2 over the existing structure.

$$P_{4_{c-a}} = \left(\frac{T_{4_a} - T_{4_c}}{D}\right)\left(\text{Present value of the DEH inventory at Fort Benning under the existing structure}\right)$$

T_{4_a} = Total vehicle days down per year for organizational maintenance cases under the existing structure at Fort Benning = (5.208) (7324 ÷2) = 19071.7 vehicle days.

T_{4_c} = Total vehicle days down per year for organizational maintenance cases if Fort Benning was alternative structure 2.

$$T_{4_c} = (5.208)\ \frac{45.287}{17.68}\ (7324 \div 2).$$

$$T_{4_c} = (13.34)(3662) = 48851.08 \text{ vehicle days.}$$

D = Total available vehicle days = (1184 vehicles)(260 days) = 307840 vehicle days.

$$P_{4_{c-a}} = \left(\frac{19071.7 - 48851.08}{307840}\right)(9{,}000{,}000)$$

$$P_{4_{c-a}} = (-0.0967)(9{,}000{,}000) = -\$870628.96.$$

D.5 <u>Calculation of $P_{5_{c-a}}$</u>

$P_{5_{c-a}}$ = Annual intermediate maintenance cost difference related to the change in utilization due to choosing alternative structure 2 over the existing structure (baseline) at Fort Benning.

$$P_{5_{c-a}} = \left[1 - \frac{1}{\left(1 - \frac{T_{3_a} - T_{3_c}}{D}\right)}\right] P_{1_a}$$

Since $T_{3_a} - T_{3_c} = 0.$

$$P_{5_{c-a}} = 0.$$

D.6 <u>Calculation of $P_{6_{c-a}}$</u>

$P_{6_{c-a}}$ = Annual organizational maintenance cost difference related to the change in utilization due to choosing alternative structure 1 over the existing structure at Fort Benning.

$$P_{6_{c-a}} = \left[1 - \frac{1}{\left(1 - \frac{T_{4_a} - T_{4_c}}{D}\right)}\right] P_{2_a}$$

$$P_{6_{c-a}} = \left(1 - \frac{1}{1 - \frac{19071.7 - 48851.08}{307840}}\right) P_{2_a}$$

$$= \left[1 - \frac{1}{1 + (0.096736)}\right](158418.96)$$

$$= \left(1 - \frac{1}{1.096736}\right)(158,418.96) = 13973.19$$

D.7 Calculation of $P_{7_{c-a}}$

P_{7_c} = Annual inspection cost of the intermediate maintenance cases at Fort Benning if it was alternative structure 2.

$P_{7_c} = (t_{1_c})(n_1)(e_{3_c})$

t_{1_c} = Estimated average time spent for the inspection of an intermediate maintenance case under alternative structure 2 = 4 1/4 hours.

n_1 = Number of intermediate maintenance cases per year at Fort Benning = (171 ÷ 2) = 86.

e_3 = Effective shop rate of Fort Benning if it was alternative structure 2 = \$13.80.

P_{7_c} = (4 1/4)(86)(13.80) = \$5043.90

$P_{7_{c-a}}$ = Annual inspection cost difference for intermediate maintenance cases at Fort Benning when choosing alternative structure 2 over the existing structure (baseline).

$P_{7_{c-a}} = P_{7_a} - P_{7_c}$ = \$7399.44 - \$5043.90 = \$2355.54.

(For P_{7_a}, see paragraph C.7.)

D.8 Calculation of $P_{8_{c-a}}$

P_{8_c} = Annual inspection cost of the organizational maintenance cases at Fort Benning under alternative structure 2.

$P_{8_c} = (t_{2_c})(n_2)(e_4)$

t_{2_c} = Estimated average time spent for the inspection of an organizational maintenance case under alternative structure 2 = 2 1/4 hours.

n_2 = Number of organizational maintenance cases per year at Fort Benning = 3662.

e_4 = Effective shop labor rate if Fort Benning was alternative structure 2 = \$13.80.

P_{8_c} = (2 1/4)(3662)(13.80) = \$113,705.10.

$P_{8_{c-a}}$ = Annual inspection cost difference for the organizational maintenance cases at Fort Benning when choosing alternative structure 2 over the existing structure.

$P_{8_{c-a}} = P_{8_a} - P_{8_c}$ = \$63554.01 - \$113,705.10 = -\$50,151.09.

(For P_{8_c}, see paragraph C.8.)

D.9 <u>Calculation of $P_{9_{c-a}}$</u>

$P_{9_{c-a}}$ = Annual transportation cost difference for intermediate maintenance cases at Fort Benning when choosing alternative 2 over the existing structure.

$P_{9_{c-a}} = P_{9_a} - P_{9_c}$ = \$2985.06 - 0 = \$2985.06.

(For P_{9_a}, see paragraph C.9.)

D.10 <u>Calculation of $P_{10_{c-a}}$</u>

P_{10_c} = Annual cost associated with the parts ordering process for intermediate maintenance cases at Fort Benning under the alternative structure 2.

$P_{10_c} = (t_{4_c})(n_1)(e_6)$

t_{4_c} = Estimated average time spent for parts ordering process for an intermediate maintenance case at Fort Benning under alternative structure 2 = 3/4 hours.

n_1 = Number of intermediate cases per year at Fort Benning = 86.

e_6 = Effective shop labor rate if Fort Benning was alternative structure 2 = \$13.80.

P_{10_c} = (3/4)(86)(13.80) = \$890.10.

$P_{10_{c-a}}$ = Annual cost difference associated with the parts ordering process for intermediate maintenance cases at Fort Benning when choosing alternative2 over the existing structure.

$P_{10_{c-a}} = P_{10_a} - P_{10_c}$ = \$890.10 - \$890.10 = 0.

(For P_{10_a}, see paragraph C.10.)

D.11 <u>Calculation of $P_{11_{c-a}}$</u>

P_{11_c} = Annual cost associated with the parts ordering process for organizational maintenance cases at Fort Benning under alternative 2.

$P_{11_c} = (t_{5_c})(n_2)(e_7)$

t_{5_c} = Estimated average time spent for parts ordering process for an organizational maintenance case at Fort Benning under alternative 2 = 3/4 hours.

n_2 = Number of organizational maintenance cases per year at Fort Benning = 3662.

e_7 = Effective shop labor rate of Fort Benning under alternative 2 = \$13.80.

P_{11_c} = (3/4)(3662)(13.80) = \$37901.70.

$P_{11_{c-a}}$ = Annual cost difference associated with the parts ordering process for organizational maintenance cases at Fort Benning when choosing alternative 2 over the existing structure.

$P_{11_{c-a}} = P_{11_a} - P_{11_c}$ = \$42369.34 - 37901.70 = \$4467.64.

(For P_{11_a}, see paragraph C.11.)

APPENDIX E:

DETERMINATION OF PARAMETERS FOR FORT BENNING DEH WHEN COMPARING ALTERNATIVE STRUCTURE 1 WITH ALTERNATIVE STRUCTURE 2

E.1 Calculation of $P_{1_{b-c}}$

$P_{1_{b-c}}$ = Annual cost difference for intermediate level maintenance cases when choosing alternative structure 1 over the alternative structure 2.

$P_{1_{b-c}} = P_{1_c} - P_{1_b}$ = \$39757.80 = \$38663.02 = \$1094.78.

(See paragraph C.1 for P_{1_b} and D.1 for P_{1_c}.)

E.2 Calculation of $P_{2_{b-c}}$

$P_{2_{b-c}}$ = Annual cost difference for organizational level maintenance when choosing alternative structure 1 over alternative structure 2.

$P_{2_{b-c}} = P_{2_c} - P_{2_b}$ = \$188952.61 - \$183749.57 = \$5203.04.

(See paragraph C.2 for P_{2_b} and D.2 for P_{2_c}.)

E.3 Calculation of $P_{3_{b-c}}$

$P_{3_{b-c}}$ = Annual cost difference related to the change in DEH inventory for intermediate maintenance cases due to choosing alternative structure 1 over alternative 2.

$$P_{3_{b-c}} = \left(\frac{T_{3_c} - T_{3_b}}{D}\right)\left(\begin{array}{l}\text{Present value of the DEH} \\ \text{inventory at Fort Benning}\end{array}\right)$$

$$P_{3_{b-c}} = \left[\frac{3872.02 - 967}{(1184)(260)}\right](9{,}000{,}000)$$

$$P_{3_{b-c}} = (0.0094)(9{,}000{,}000) = \$84931.$$

(See paragraph C.3 for T_{3_b} and D.3 for T_{3_c}.)

E.4. Calculation of $P_{4_{b-c}}$

$P_{4_{b-c}}$ = Annual cost difference related to the change in DEH inventory for organizational maintenance cases due to choosing alternative 1 over alternative 2.

$$P_{4_{b-c}} = \left(\frac{T_{4_c} - T_{4_b}}{D}\right)\left(\begin{array}{l}\text{Present value of the DEH}\\ \text{inventory at Fort Benning}\end{array}\right)$$

$$P_{4_{b-c}} = \left[\frac{48851.08 - 19071.7}{(1184)(260)}\right](9{,}000{,}000)$$

$$P_{4_{b-c}} = (.09674)(9{,}000{,}000) = \$870628.96.$$

(See paragraph C.4 for T_{4_b} and D.4 for T_{4_c}.)

E.5 Calculation of $P_{5_{b-c}}$

$P_{5_{b-c}}$ = Annual intermediate maintenance cost difference related to the change in utilization due to choosing alternative structure 1 over alternative 2.

$$P_{5_{b-c}} = \left[1 - \frac{1}{\left(1 - \frac{T_{3_c} - T_{3_b}}{D}\right)}\right] P_{1_a}$$

$$P_{5_{b-c}} = \left[1 - \frac{1}{1 - \frac{3872.02 - 967}{(1184)(260)}}\right] P_{1_a}$$

$$P_{5_{b-c}} = (-.00953)(33333.17) = -\$317.56.$$

(See paragraph C.3 for T_{3_b} and D.3 for T_{3_c}.)

E.6 Calculation of $P_{6_{b-c}}$

$P_{6_{b-c}}$ = Annual organizational maintenance cost difference related to the change in utilization due to choosing alternative structure 1 over alternative 2.

$$P_{6_{b-c}} = \left[1 - \frac{1}{\left(1 - \frac{T_{4_c} - T_{4_b}}{D}\right)}\right] P_{2_a}$$

$$P_{6_{b-c}} = \left[1 - \frac{1}{1 - \left(\frac{48851.08 - 19071.7}{307840}\right)}\right](158,418.96)$$

$$P_{6_{b-c}} = \left[1 - \frac{1}{1 - (0.096736)}\right](158418.96)$$

$$P_{6_{b-c}} = (-.1071)(158,418.96) = -\$16966.15.$$

(See paragraph C.4 for T_{4_b} and D.4 for T_{4_c}.)

E.7 <u>Calculation of $P_{7_{b-c}}$</u>

$P_{7_{b-c}}$ = Annual inspection cost difference for the intermediate maintenance cases at Fort Benning when choosing alternative 1 over alternative 2.

$$P_{7_{b-c}} = P_{7_c} - P_{7_b}$$

$$P_{7_{b-c}} = \$5043.90 - \$2308.24 = \$2735.66.$$

(See paragraph C.7 for P_{7_b} and D.7 for P_{7_c}.)

E.8 <u>Calculation of $P_{8_{b-c}}$</u>

$P_{8_{b-c}}$ = Annual inspection cost difference for the organizational maintenance cases at Fort Benning when choosing alternative 1 over alternative 2.

$$P_{8_{b-c}} = P_{8_c} - P_{8_b}$$

$$= \$113,705.10 - \$73716.06 = \$39,989.04.$$

(See paragraph C.8 for P_{8_b} and D.8 for P_{8_c}.)

E.9 <u>Calculation of $P_{9_{b-c}}$</u>

$P_{9_{b-c}}$ = Annual transportation cost difference for intermediate maintenance cases at Fort Benning when choosing alternative 1 over alternative 2.

$P_{9_{b-c}} = P_{9_c} - P_{9_b} = 0$ (since $P_{9_b} = P_{9_c} = 0$)

(See paragraph C.9 for P_{9_b} and P_{9_c}.)

E.10 <u>Calculation of $P_{10_{b-c}}$</u>

$P_{10_{b-c}}$ = Annual cost associated with the parts ordering process for intermediate maintenance cases at Fort Benning when choosing alternative 1 over alternative 2.

$P_{10_{b-c}} = P_{10_c} - P_{10_b}$ = \$890.10 = \$1442.65 = -552.55.

(See paragraph C.10 for P_{10_b} and D.10 for P_{10_c}.)

E.11 <u>Calculation of $P_{11_{b-c}}$</u>

$P_{11_{b-c}}$ = Annual cost associated with the parts ordering process for organizational maintenance cases at Fort Benning when choosing alternative 1 over alternative 2.

$P_{11_{b-c}} = P_{11_c} - P_{11_b}$ = \$37901.70 - \$48875.64 = \$10973.94.

(See paragraph C.11 for P_{11_b} and D.11 for P_{11_c}.)

GLOSSARY

DEH: Directorate of Engineering and Housing

DIO: Directorate of Industrial Operations

effective shop labor rate: Hourly labor rate which includes administrative and operational overhead costs.

intermediate maintenance: Maintenance operations which include the following as defined in AR 750-1:

(1) Diagnosis and isolation of materiel or module malfunctions, adjustment, and alignment of modules which can be readily completed with assigned tools.

(2) Repair of unserviceable economically repairable materiel, which is beyond the capability of using activities. It will be on a repair and return to the user basis.

(3) Module and component disassembly and repair which are normally limited to tasks requiring the cleaning and replacement of seals, fittings, transistors and resistors, replaceable parts, common hardware, or repair kits as authorized by the maintenance allocation chart of the respective module or component.

(4) Performance of pollution evaluations of emissions from internal combustion engine-powdered material and the necessary adjustment, replacement or repairs to sustain these emissions within established standards.

(5) Performance of light body repairs to include straightening, welding, sanding, and painting of skirts, fenders, body and hull sections.

(6) Provision of quick reaction materiel readiness and technical assistance support to organizational maintenance elements including:

(a) Inspection of maintenance operations and materiel of supported activities to determine the efficiency and effectiveness of these operations and detect materiel failures.

(b) Advising and instructing personnel of these elements in the proper methods of performing organizational maintenance.

(c) Highly mobile maintenance support teams to perform or assist in the performance of authorized malfunction diagnoses, adjustment, alignment, repair and replacement of modules and end items on-site as required.

(7) Evacuation of unserviceable end items and modules to designated facilities of the same or higher categories of maintenance when their repair is beyond the authorized capability/capacity.

organizational maintenance: Maintenance operations which include the following as defined in AR 750-1:

(1) Inspections by sight and touch of external and other easily accessible components; lubrication, cleaning, preserving (to include painting), tightening, and minor adjustments to easily accessible mechanical, electrical, hydraulic, and pneumatic systems.

(2) Diagnosis and isolation of material malfunctions which can be readily traced to a defective module by easy to use and interpret external diagnostic and fault isolation devices such as automatic test equipment.

(3) Replacement of modules authorized by the maintenance allocation chart on a time change basis or those identified as worn, damaged, or otherwise defective which (a) can be readily removed and installed with easy to use tools, and (b) do not require critical adjustment, calibration, or alignment before or after installation.

(4) Replacement of easily accessible unserviceable parts usually not requiring special tools or test material (for example knobs, lamps, fan belts, wheels, tires, filter elements, firing pins, gauges, and expendable antenna).

(5) Maintenance evacuation of malfunctioning materiel and modules (properly preserved, protected, or tagged), which are beyond authorized capability or capacity to repair or replace, to selected supporting maintenance facilities for repair or exchange for like serviceable materiel when these activities can not provide the required support on-site.

vehicle equivalent (as defined in AF Manual, Volume 2): A unit of measure that denotes the maintenance complexity of a vehicle or item of equipment based on the maintenance complexity of a sedan-general purpose and commercial design.

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